1943

Project: No. X-128 (Av-C3-1)

COMPARATIVE TESTING OF ELECTRICALLY HEATED FLYING SUITS

(TAYLOR SUIT VERSUS U. S. NAVY SUIT)

From

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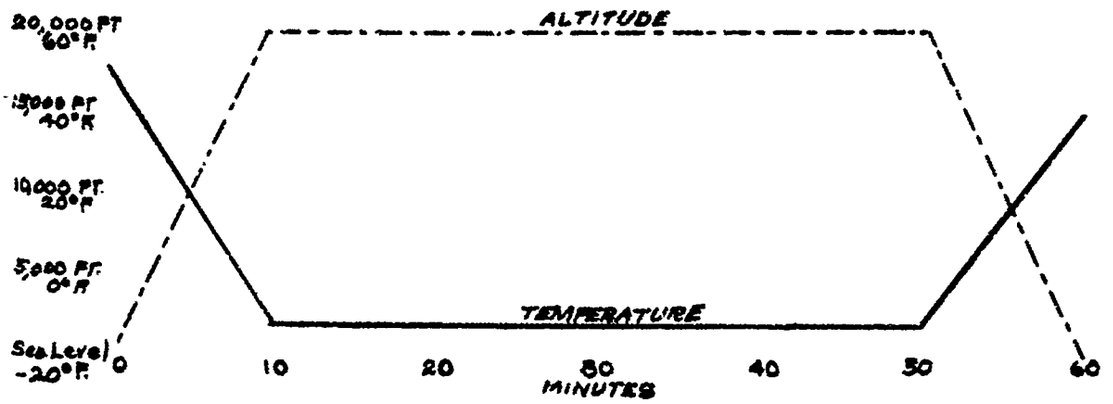
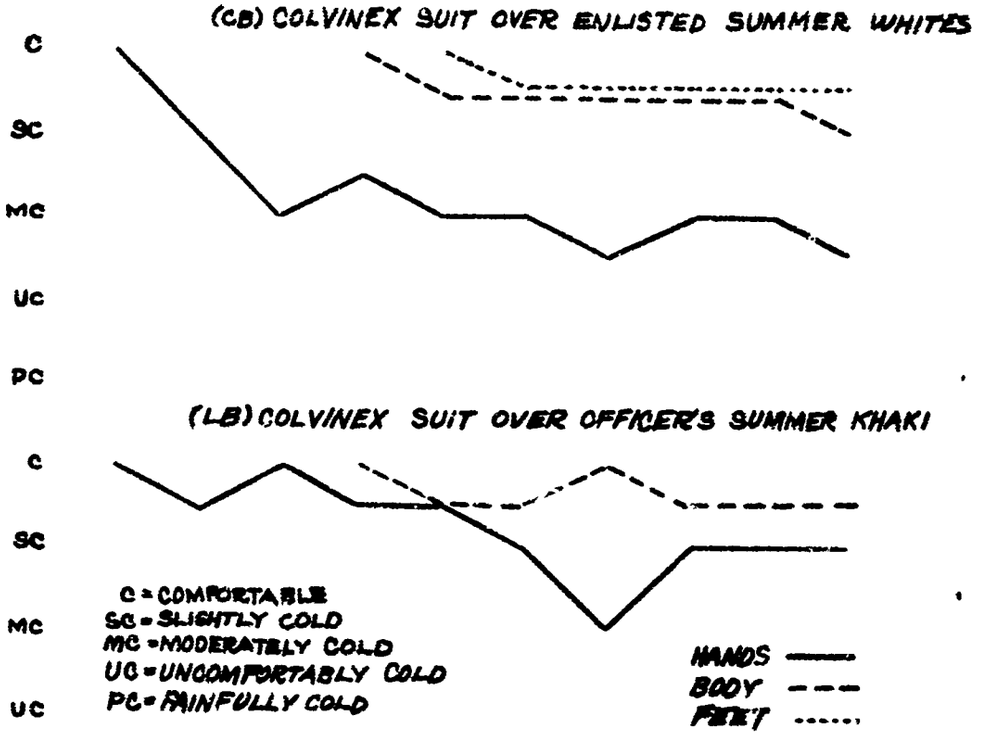
FIGURE 1


20,000 FT
60°F
15000 FT
40°F
10,000 FT
20°F
5,000 FT
0°F
Sea Level
-20°F
ALTITUDE
TEMPERATURE
0
10
20
30
40
50
60
MINUTES


(CB) COLVINEX SUIT OVER ENLISTED SUMMER WHITES
C
SC
MC
UC
PC
(LB) COLVINEX SUIT OVER OFFICER'S SUMMER KHAKI
C
SC
MC
UC
PC
C = COMFORTABLE
SC = SLIGHTLY COLD
MC = MODERATELY COLD
UC = UNCOMFORTABLY COLD
PC = PAINFULLY COLD
HANDS
BODY
FEET
(LH) TAYLOR SUIT OVER OFFICER'S SUMMER KHAKI
C
SC
MC
UC

SUMMARY:

The Colvinex electrically heated flying suit and the Taylor (British) electrically heated suit with flotation gear were compared from the following points of view:

a. Construction
b. Electrical characteristics
c. Wearing characteristics, comfort, etc.
d. Protection against cold

In addition, the Taylor suit was examined as to its flotation characteristics.

A. Construction: The body and boots of both suits were of excellent general construction. However, in respect to gloves and zippers the Taylor suit was thought to be definitely superior in all respects.

B. The electrical characteristics of the Taylor suit are superior to those of the Colvinex suit in respect to connections. Actually and theoretically, less wattage is necessary to heat the former. The Taylor suit is designed for a three wire circuit and has no switch. The Colvinex suit has a switch which seems to be designed for a system with higher voltage.

C. The Colvinex suit with a standard Navy inflatable jacket was much more comfortable than the Taylor suit. Practiced individuals could put on and take off the two suits in about the same amount of time (90 seconds and 20 seconds respectively).

Ordinarily airplane generators in Navy planes are capable of providing adequate potential and current to heat the suits. Assuming a suit is to be worn by each crew member, the possibility of overloading the generators is very definite in certain types of planes. If, however, the suit is to be worn only by those who most need them (such as rear cockpit gunners), the chances of overloading are small.

D. The Taylor suit is superior to the Colvinex in respect to protection against cold especially as far as the Taylor gloves are concerned. However, as one would suspect, neither suit is completely satisfactory in this respect. These tests were performed in the chill chamber, a.) at sea leavel at -40°F, and b.) at 20,000 ft. at -13°F.

The Taylor suit is capable of providing ample flotation to an individual with either kapok alone or air alone. Optimum flotation is secured by the use of both air and Kapok.

The electrical heating system of the Taylor suit was no longer functioning after being submerged in salt water and properly dried.

CONCLUSIONS:

The Taylor suit is superior to the Navy suit in respect to construction, electrical characteristics, and protection against cold.

The Colvinex suit is more comfortable than the Taylor suit.

RECOMMENDATIONS:

Certain aspects of the Taylor suit, notably the gloves, zippers, and electrical connections, could beneficially be incorporated into the Colvinex suit.

COMPARISON OF COLVINEX AND TAYLOR ELECTRICALLY HEATED FLYING SUITS

The Colvinex electrically heated flying suit and the Taylor (British) electrically heated suit with flotation gear were compared from the following points of view:

a. Construction
b. Electrical characteristics
c. Wearing characteristics, comfort, etc.
d. Protection against cold

In addition, the Taylor suit was examined as to its flotation characteristics.

A. CONSTRUCTION

SUIT: Both suits are of good construction. The materials used are excellent, with one exception. The lining of the Colvinex suit is of muslin, and should soon show signs of wear, particularly under the arm pits. The Taylor lining is of more durable material. The Colvinex shoulder strap for suspension is of wide cloth, which wrinkles easily.

ZIPPER: The slide fastener used in the Taylor suit is of excellent construction - sticking and catching did not occur in many attempts to "zip" the suit. The quick release feature is an advantage, although it did not contribute to increased speed in getting out of the suit. (See C below) The Colvinex zipper is of poor construction, sliding sometimes with difficulty, sticking and catching on occasion. The device for starting the zipper is superior in the Taylor suit.

In the Colvinex suit, the croton piece starts to zip at the top, superior for putting on the suit than in the Taylor, which starts at the legs. The Colvinex suit for urination has two flaps to the Taylor's one, being better protected, but making urination more difficult due to constriction.

GLOVES: Two types of Taylor gloves were furnished, one with removable inner heated lining, and the other with heat incorporated into the glove itself. The Taylor gloves were far superior to the Colvinex: (a) A gauntlet extended well over the wrist and sleeve of the jacket, preventing gaps at the wrists, as in the Colvinex. (b) There was no constriction in the fingers as in the Colvinex. (c) Construction was better. The Taylor gloves were somewhat bulkier and less mobile than the Colvinex, but this did not interfere with writing. When

the outer glove was removed and only the inner silk heated lining used, mobility was excellent, better than the Colvinex.

FOOTGEAR: Workmanship on both types of foot gear, boots and slippers, was excellent. The Colvinex boot gave excellent protection against cold without being heated.

B. ELECTRICAL CHARACTERISTICS

Six Colvinex suits, 12 gloves, and 12 boots were examined as to electrical characteristics; as were a Taylor suit, a Taylor vest, 4 gloves, and 4 slippers.

Since heat production depends upon resistance, all units were tested with an ohmmeter for variations (Table I). The Colvinex gloves varied from 11.1 to 10.25 ohms, a difference of about 8%. In all cases but one the right glove, has a lower resistance than the left (which would make it warmer). The boots varied between 10.0 and 9.0 ohms, a difference of 10%. The whole suits varied from 0.99 to 1.3 ohms, a difference of 27.3%. Suits connected to gloves and boots varied from 0.6 to 0.8 ohms, a difference in heat production of 25%.

Two of the 12 gloves were found to be defective, in that the resistance varied 2.0 and 6.0 ohms when the fingers were clenched. One suit varied 0.1 ohm when parts were moved, which would change its heat production 8%.

The Taylor suit could not be as readily compared, since there were fewer units provided. (Table II) The 4 gloves varied from 9.0 to 11.0 ohms, the right glove being in both cases higher (colder). Resistance was 1.0 ohm lower in those with removable linings. The slippers were quite constant at 11.0 ohms with the exception of 1, 10.8 ohms. Neither suit, vest, gloves nor slippers varied with movement.

The electrical connections of the Colvinex suit were considerably inferior to those of the Taylor. The snaps provided for attaching gloves and boots were of poor construction, considering the low voltages and high amperages utilized. In four of six suits the snaps between leg and boot were insufficient to provide adequate flow of current, and in three inadequate to remain snapped. These snaps were easily bent and broken.

The Taylor snaps, on the other hand, provided solid low resistance connections through the wire ring in the female part. They were stiffer and in no case did they come apart without considerable effort.

The Colvinex switch is the standard make used in 110 volt heating pads. There are four degrees of heat - OFF, which heats gloves and boots only; LOW, MEDIUM and HIGH. Variations in the resistance of the whole suit at single settings of three switches amounted to 1.0 ohm (out of 1-2 ohms), an increase (and therefore decrease of theoretical warmth) of as much as 50%; in the other three the variation was 0.5 ohm. Obviously such a switch is unsuitable for low voltage-high amperate connections. No switch was provided for the Taylor suit.

Theoretical wattages calculated at various voltages showed that the Colvinex suit gave higher output at the same voltage than the Taylor suit. When tested on a loaded airplane generator, this was found to be the case, although in both instances the wattage developed was lower than theoretical (Table III). A little more than 13 volts was necessary to produce the wattage rated for the Taylor suit; that rated for the Colvinex is not known, but at 13 volts it develops 214 watts, a figure close to the theoretical calculated from its resistance.

Theoretical and actual wattages of the various gloves and foot gear showed roughly that more heat is delivered to the hands by the Taylor suit and more to the feet by the Colvinex. The proportion of total heat produced delivered to the extremities is: Colvinex 30%, Taylor 40%. It must be remembered, however, that the Taylor suit is made of a better insulating material, and therefore the body unit requires less heat.

At least it can be stated that both suits at 12 volts produce insufficient heat to provide adequate protection, and in the case of the Taylor, where the required wattage is known, this amounts to only about 80% of the amount necessary.

In all the trials with the Colvinex suit, there was no occasion on which current short-circuited through the body. On one occasion, wearing the Taylor vest, an observer who had perspired profusely in his axillae became uncomfortably aware of the passage of current through his body. This disappeared when dry wool under-clothes were worn. It was further noted that the electrical system of the Taylor suit, after being submerged for 20 minutes in salt water, then properly dried, no longer functioned as a heating unit.

C. WEARING CHARACTERISTICS

Both types of suits were tested under flight conditions in PBY type planes, without heating. There was no doubt that the Colvinex suit with standard Navy inflatable life jacket was

much more comfortable than the Taylor. The latter was bulky, restricted free motion of the head and thorax, restricted bending down, and was rough (without a scarf) against the chin. At 0° C in the closed after compartment of a PBY both suits were insufficient to maintain resting body warmth, the Taylor affording slightly more protection. Because of the bulkiness of the Taylor suit, it felt heavier, although it weighs only 2 lbs. more. The bulkiness was due in large part to the kapok flotation gear.

It was possible, owing to the excellent construction of the Taylor zippers, to put it on as quickly as the Colvinex suit, in spite of its bulk. A practiced individual was able to get into each of the two types of suits in approximately 1-1/2 minutes. Individuals were able to take off the Taylor suit on land in about 5 seconds less than the Colvinex, which took about 20 seconds.

CURRENT DELIVERED BY AEROPLANE GENERATORS: An examination of the available specifications of different type Navy planes showed that the generators now in use are set by voltage regulators to deliver 14-1/2 volts, or 29 volts. These generators usually have an equal "reserve", a 14-1/2 volt one being able to develop 28 volts. This is required in order that the voltage may remain constant at various engine speeds. It is probable that the line drop between generator and suit may amount to as much as 1/2 volt - This was the case in a test generator set-up. Therefore, for all practical purposes the suits will be operated in planes at 14 or 28 volts. Under present conditions, if all members of a crew of aircraft were equipped with electrically heated suits (Colvinex) developing 250 watts at 14 volts, there would be serious danger of overloading generators in most types of Navy planes with standard equipment (Table III). These suits could probably be used in some torpedo bombers, one scout bomber, and all of the fighters, except when the generators were under peak loads.

TABLE I

RESISTANCES OF VARIOUS UNITS OF COLVINEX AND TAYLOR SUITS (OHMS)

SAMPLE	GLOVES L.	GLOVES R.	BOOTS L.	BOOTS R.	COLVINEX SUIT — SUIT ALONE Low	Med.	High	SUIT COMPLETE Off	Low	Med.	High	SWITCH Variation
1	*11.0	10.7	9.5	9.5	2.5	1.6	1.0	2.6	1.2	1.0	0.7/	/0.5
2	10.5	10.3	9.0	9.5	3.0	1.9	1.3	2.5	1.6	1.0	0.8	/0.5
3	11.0**	10.8	9.4	9.6	2.6	1.7	1.0	2.5	1.3	1.1	0.6	/1.0
4	11.1	10.8	9.3	9.6	2.7	1.6	1.0	2.6	1.3	1.0	0.7	/0.5
5	11.0	10.5	9.5	9.5	2.8	1.5	1.0	2.5	1.3	1.0	0.7	/1.0
6	10.4	10.6	10.0	9.4	3.0	2.2	0.95	2.5	1.3	1.1	0.75	/1.0
%variation	6.5	5.0	10.0	2.0	16.6	33.0	27.3	3.5	25.0	9.0	25.0	
approx. watts (theoretical) 12V.	13.4	13.7	15.2	15.2	53	80	131	56	105	137	210	
TAYLOR SUIT												
1. (Coat lined gloves)	9.0	9.5	11.0	10.8	1.7					1.0		
Theoretical watts 12V	16.0	15.2	13.1	13.3	84.7			57.6		144		
2. (Vest unlined gloves	10.0	11.0	11.0	11.0	2.3					1.2		
Theoretical watts 12V	14.4	13.1	13.1	13.1	62.5			53.7		120		

*Glove # 1 varied 2.0 ohms when fist was clenched.
**glove # 3 varied 6.0 ohms when fist was clenched.
/Suit # 1 varied 0.1 ohms when moved and shaken gently.

Note: The wattages calculated for each Colvinex unit are the mean of the variations found. Switch variations in ohms are those at several settings of the switch. At the high position there was less variation with each successive try.

In the off position, the Colvinex suit delivers current to the extremities only. Watts developed by the Taylor suit, gloves and boots were calculated by adding those of each unit.

TABLE II

WATTS DEVELOPED AT VARIOUS VOLTAGES OF AIRPLANE GENERATION BY BEST COLVINEX AND TWO TAYLOR SUITS

VOLTAGE	SUIT ALONE			GLOVES AND BOOTS ONLY	WHOLE SUIT		
	Low	Med.	High		Low	Med.	High
COLVINEX (Theoretically 210 watts)							
11	44	72	114	40	88	113	154
12	54	84	128	50	100	121	180
13	60	98	160	59	120	156	214
14	70	116	182	70	140	182	250
TAYLOR SUIT (Rated 150 watts)							
11			66	40			105
12			78	45			123
13			84	61			145
14			105	63			168
TAYLOR VEST (Rated 120 watts)							
11			45	40			85
12			54	46			100
13			65	52			117
14			72	74			136

TABLE III

CAPACITY OF GENERATORS OF VARIOUS NAVY AIRCRAFT

Type of Plane	Volts	Amperes	Watts	No. in Crew max.	Max. Watts Needed For Suits	Possibility of Overload
PBY2	15	30	450	9	2250	yes
PBY5A	30	25	750	9	2250	yes
PBY5B	30	50/100	1500/3000	9	2250	yes
PB2Y	15	100	1500	10	2500	yes
PBM	30	300	9000	5	1250	no
TBD	15	30/100	450/1500	3	750	yes
TBF	30	300	9000	3	750	no
TBM	30	300	9000	3	750	no
TBV	30	300	9000	3	750	no
SBC	15	25/50/100	375/750/1500	2	500	yes
SBD	15	30/100	450/1500	2	500	yes
SBD-5	30	60/100	1800/3000	2	500	no
SB2U	15	30	450	2	500	yes
OS2U	15	25/50/100	375/750/1500	2	500	yes
F4F	15	100	1500	1	250	no
F6F	30	300	9000	1	250	no
F4U	30	60/100	1800/3000	1	250	no

NOTE: When excess loads are put on generator, as in lowering or raising wing floats or wheels, there may be overloading if suits are attached.

D. PROTECTION AGAINST COLD

METHODS: A series of runs were made in the chill chamber in order to test the suits for protection against cold at different temperatures and altitudes. The subjects who made the runs were, for the most part, individuals who were thoroughly versed in the methods of the low pressure chamber, thus minimizing the psychic factor as much as possible. Since there was but one electrically heated Taylor suit and several Colvinex suits, more observations were possible on the Colvinex suits. All observations, except for actually observing a person shiver or palpating a very cold hand were necessarily of a subjective nature.

Voltages used were comparable to those generated in the usual types of Naval aircraft.

Generally, there were two types of runs: The first type of run consisted of simply lowering the temperature inside the chamber to 40° below zero Fahrenheit in about 15-20 minutes and waiting for the suits to "break". Admittedly this was an extremely stern test, the point of which was to see which suit afforded the least protection, being reasonably sure that neither could afford enough protection to make the wearer comfortable. These conditions were maintained until the subjects could no longer stand the cold. The second type of run was designed to test the suits for protection at -13°F. at 20,000 feet, which is theoretically the point on the temperature-altitude curve at which conditions to which a rear cockpit gunner would be subjected are most severe. The temperature was lowered from about 50°F. to -13°F. in a period of ten minutes during which time the altitude was raised from sea level to 20,000 feet. These conditions were maintained for 1 hour or more. Having recorded the clothing worn by each of the subjects, an observer on the outside of the chamber inquired as to the condition of each of the subjects at intervals of 5 minutes and made records on sheets mimeographed for this purpose (enclosed). As the subject was interrogated about each part of his anatomy, he was instructed to reply that it was either comfortable, slightly cold, moderately cold, uncomfortably cold, painfully cold, or numb. In this manner an attempt was made to obtain a quantitative estimate of the progress of each individual. These results were later expressed graphically. (Observations were also made on the masks and goggles which are not recorded in this study.)

RESULTS: T. -40°F. SEA LEVEL

IN 20 OBSERVATIONS ON THE COLVINEX HEATED SUIT:

(a) The feet became uncomfortably or painfully cold on 7 occasions.
(b) The hands became uncomfortably or painfully cold on 20 occasions.
(c) The body became uncomfortably cold on 22 occasions.

IN 5 OBSERVATIONS ON THE TAYLOR HEATED SUIT:

(a) The feet became uncomfortably or painfully cold on no occasions.
(b) The hands became uncomfortably or painfully cold on 2 occasions.
(c) The body became uncomfortably or painfully cold on no occasions.

In 2 observations each on the Taylor unheated suit and the Colvinex unheated suit the subjects became uncomfortably cold all over (hands, feet, and body) in less than 20 minutes at this temperature.

T. -13°F. ALT. 20,000 FT.

IN 13 OBSERVATIONS ON THE COLVINEX HEATED SUIT

(a) The feet became uncomfortably or painfully cold on 3 occasions.
(b) The hands became uncomfortably or painfully cold on 10 occasions.
(c) The body became uncomfortably or painfully cold on 4 occasions.

IN 5 OBSERVATIONS ON THE TAYLOR HEATED SUIT:

(a) The feet became uncomfortably or painfully cold on 1 occasion.
(b) The hands became uncomfortably or painfully cold on 1 occasion.
(c) The body became uncomfortably or painfully cold on no occasion.

(See enclosed graphs for examples of typical runs.)

TABLE OF RESULTS

-40°F.	SEA LEVEL			
SUIT	# OBSERVATIONS	PART	# FAILURES	% FAILURES
Colvinex with heat	26	Feet	7	27%
Colvinex with heat	26	Hands	20	77%
Colvinex with heat	26	Body	22	[illegible]
Taylor with heat	5	Feet	0	0%
Taylor with heat	5	Hands	2	40%
Taylor with heat	5	Body	0	0%
Colvinex without heat	2	All	2	100%
Taylor without heat	2	All	2	100%
-13°F.	20,000 FT.			
Colvinex with heat	13	Feet	3	23%
Colvinex with heat	13	Hands	10	77%
Colvinex with heat	13	Body	4	31%
Taylor with heat	5	Feet	1	20%
Taylor with heat	5	Hands	1	20%
Taylor with heat	5	Body	0	0%

It was thought that the Colvinex suits varied among themselves for two reasons:

1. A certain suit consistently kept its subject warmer than did the others.

2. After heating two suits for 1/2 hour each at the same temperature and under the same condition, the gloves of one suit were markedly much warmer than those of the other suit. This may have been due to the uncertain electrical connections of the Colvinex suit (see above).

DISCUSSION: There seems to be a question among those who have been working with low temperature as to whether the resistance of a given individual varies from day to day or whether there is a change in resistance from one individual to another. Some feel that all men are equally resistant to cold but vary according to what they have eaten recently, their present physical condition, the time of year, etc., while according to others each man is different. Since either or both of these conditions may be true, testing of a specially prepared mannikin is probably the best method for accurately comparing two suits. However, the actual wearing of the suit must eventually be the real test and since the results above are fairly consistent in most cases, it seems fair to assume that generally speaking, the Taylor gloves and suit afford better protection against cold, whereas both sets of boots when heated are equally efficient in protecting the feet of the wearer against low temperatures.

FLOTATION CHARACTERISTICS OF TAYLOR SUIT

With the cooperation of Lt. (j.g.) Zwierlein of the athletic department, the Taylor suit was tested for flotation by actually wearing it into the salt water of the Gulf. Four tests were performed.

First, the suit was tested by wearing it into the water with both Kapok and air flotation.

Second, it was tested in an identical manner without air flotation.

Third, it was tested with the Kapok removed but with air flotation.

Fourth, it was tested by submerging the suit by means of weights for 12 hours, then trying its flotation characteristics again by the same method.

On all four occasions the subject who wore the suit was as comfortable as could be expected and well suspended with his chin at least 3 inches above the surface of the water. The subject also noticed that he was automatically turned on his back and was unable to remain in any other position without a certain amount of struggle. This is considered advantageous, and is particularly true in case of combined air and Kapok flotation.

NUMBER AND NAME	SUIT	HEAD	NECK	TRUNK	UPPER EXTREMITIES: Arms	UPPER EXTREMITIES: Hands	LOWER EXTREMITIES: Legs	LOWER EXTREMITIES: Feet	GLOVES	MASK	OTHER
1.											
2.											
3.											
4.											
5.											
6.											

DATE:
TIME:
  Hour:
  Time at given temp:
TEMP:
ALTITUDE:

C =Comfortable
SC=Slightly cold
MC=Moderately cold
UC=Uncomfortably cold
PC=Painfully cold
N =Numb

GOGGLES -% visibility
MASK -VNF=valve not functioning
Degree of moisture or ice
S =Slight
M =Moderate
C =Copious
Flexibility of rubber
MS=Moderately stiff
S =Stiff